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Pervious Concrete: A Concrete Step towards the Greener Earth

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ABSTRACT

In this paper, a pervious concrete pavement material used for roadway and footpath is introduced. Using the common material and method, the strength of the pervious concrete is low. Using smaller sized aggregate, silica fume (SF), and superplasticizer (SP) in the pervious concrete can enhance the strength of pervious concrete greatly. The pervious pavement materials that composed of a surface layer and a base layer were made. The compressive strength of the composite can reach 30 MPa .The water penetrations, abrasion resistance, and freezing and thawing durability of the materials are also very good. It can be applied to both the footpath and the vehicle road. It is an environment-friendly pavement material,and also the costs of pervious paver blocks are very low as compared to traditional pavers.

KEYWORDS

Concrete, Permeability, Mechanicalproperties, Durability

1. INTRODUCTION

Pervious concrete is a type of concrete with high porosity. It is used for concrete flatwork applications that allow water to pass directly through it, thereby reducing the runoff from a site and allowing groundwater recharge. The high porosity is attained by a highly interconnected void content. Typically pervious concrete has water to cementitious materials ratio (w/cm) of 0.28 to 0.40 with a void content of 18 to 35%.

The mixture is composed of cementitious materials, coarse aggregate and water with little to no fine aggregates. Addition of a small amount of fine aggregate will generally reduce the void content and increase the strength, which may be desirable in certain situations. This material is sensitive to changes in water content, so field adjustment of the fresh mixture is usually necessary. Too much water will cause paste drain down, and too little water can hinder adequate curing of the concrete and lead to surface failure. A properly proportioned mixture gives the mixture a wet metallic appearance.

Pervious concrete is used in parking areas, areas with light traffic, residential streets, pedestrian walkways, and greenhouses. It is an important application for sustainable construction and is one of the techniques used for ground water recharge.

Urbanization and the resulting increase in urban stormwater over the past few decades have led to an increase in runoff and pollution. This increase directly affects the surrounding rivers and streams, with impacts such as increased stream bank erosion, decreased water quality, and decreased base flow as areas become less and less pervious. Studies show this increase in urban stormwater runoff is a leading contributor of nonpoint source pollution in urban areas (Paul and Meyer, 2001). Such discoveries have led to a demand for innovative practices that will discourage future stream degradation and help deal with, and possibly reverse, some of the damage already done. This demand is becoming more recognized, and as a result, such technologies are emerging.

Pervious concrete pavement is an alternative to conventional impermeable pavements. Pervious concrete pavement is a type of permeable pavement; others include porous asphalt and permeable interlocking concrete pavers. Pervious concrete is currently primarily considered for low volume, low speed applications. Low volume, low speed traffic is describing personal vehicles in applications where the traffic is moving at the speed of residential neighbourhoods or less (50 km/hour maximum).

Pervious concrete pavement has been used in other areas of North America; however there has been caution in the pavement industry to implement it in climates that experience freeze-thaw cycles (NRMCA, Freeze-Thaw Resistance of Pervious Concrete, 2004).In rural areas larger amount of rainwater ends up falling on impervious surfaces such as parking lots, driveways, sidewalks, and streets rather than soaking into the soil. This creates an imbalance in the natural ecosystem and leads to a host of problems including erosion, floods, ground water level depletion and pollution of rivers, as rain water rushing across pavement surfaces picks up everything from oil and grease spills to de-icing salts and chemical fertilizers.

A simple solution to avoid these problems is to stop constructing impervious surfaces that block natural water infiltration into the soil. Rather than building them with conventional concrete, we should be switching to Pervious Concrete or Porous Pavement, a material that offers the inherent durability and low life-cycle costs of a typical concrete pavement while retaining storm water runoff and replenishing local watershed systems. Instead of preventing infiltration of water into the soil, pervious pavement assists the process by capturing rainwater in a network of voids and allowing it to percolate into the underlying soil.

1.1 Pervious Concrete Pavement

Pervious concrete pavement is a sustainable solution to a challenge that often exists in urban areas. The challenge is handling the large amount of existing impervious area in urban environments and additional area created during urban growth and development. The challenge of impermeable areas is that runoff is produced and it requires an infrastructure system for adequate control (Walker, 2009). Pervious concrete pavement has two functions: a paved surface available for low volume, low speed applications; and a stormwater management alternative. The rigid concrete creates a paved surface for various uses while the open voids in the concrete allow water to drain from the surface. Research has been done to develop pervious concrete mixes for high volume applications (PCA, 2009). In this work, only low volume and low speed applications were considered. The low volume, low speed applications that are generally considered for pervious concrete pavement are:

- Sidewalks;
- Paths;
- Driveways;
- Parking lots;
- Shoulders; and
- Residential streets.

Fig.1 Pervious concrete

Pervious concrete can be used in active or passive drainage applications and therefore reduces the demand to develop a high strength mix at this time. Active drainage occurs in scenarios when runoff from surrounding impermeable areas is drained through the pervious concrete pavement structure in addition to the precipitation occurring directly on the pervious concrete pavement. Passive drainage occurs when only precipitation falling directly on the pervious concrete pavement system is being drained through the pavement structure (PCA, 2012).

1.2 Environmental Benefits

The low impact of using pervious concrete pavement is one of the main factors attributing to the environmental benefits of this material. The drainage capabilities of pervious concrete pavement lead to developments that have minimal to no effect on the natural water cycle in the area. The reduction or often elimination of runoff in areas paved with pervious concrete pavement, in comparison to the use of an impermeable pavement, is a tremendous environmental gain. Permeable pavements are commonly referenced as Best Management Practices (BMP) for source control measures of urban stormwater management. The City of Toronto's 2003 Wet Weather Flow Management Master Plan includes porous pavement as primarily a source control method for stormwater management but also conveyance as an additional application. It notes that porous pavements reduce erosion impacts and re-establish natural hydrological processes (City of Toronto, 2003). The 2006 Halifax Regional Municipality Stormwater Management Guidelines reference permeable pavement as a common BMP in literature (Devereauz & Lorant, 2006).

Permeable pavement is referenced by many cities and municipalities throughout Canada as being a stormwater management alternative. The City of Calgary's stormwater strategy goals includes reducing both rates and volumes of stormwater runoff to protect the health of the watershed. The solution to these goals is noted as being the development and implementation of innovative stormwater alternatives in new and redeveloped areas. Sustainable streetscapes and permeable pavements are included as source control solutions (Bozic, Deong, & Fesko, 2007). The United States Environmental Protection Agency (USEPA) has acknowledged two requirements in the recent development of the National Pollutant Discharge Elimination System (NPDES). These requirements are: private and public land owners reduce the amount of stormwater runoff on their property; and reduce the contaminants in the runoff water to near pre-development levels (EPA, 2008). These reductions can be achieved by detention ponds and vegetative buffers; however, pervious concrete pavement has also been recognized as an effective tool in reducing stormwater runoff and initially treating stormwater (WERF, 2005). The USEPA has recognized the abilities of pervious concrete pavement to reduce stormwater and act as a management tool by including it as a Best Management Practice. The benefit of eliminating runoff and maintaining the local, natural hydrological cycle is substantial to the surrounding environment. The additional benefit of pervious concrete pavement, similar to any concrete pavement, is that if there is runoff over the surface, it will not become heated. Surfaces that are dark in colour such as roofs and asphalt parking lots can cause runoff that is much higher in temperature than the rainfall naturally was. Heated runoff is detrimental to aquatic life if it reaches streams and waterways (Roa-Espinosa, Norman , Wilson, & Johnson, 2003). Projects have been carried out by many groups to evaluate the ability of pervious concrete pavement to remove particulate from water that moves through the pavement structure. Pollutants that would otherwise remain in runoff and contaminate runoff have been shown to be removed during filtering through the voids in a previous concrete pavement (Tennis, Leming, & Akers, 2004).

1.3 Social Benefits

Often the environmental benefits of sustainable infrastructure alternatives are more apparent to the user than those that improve society. Pervious concrete has several attributes that can improve the quality of life for the local community. Many of the societal benefits that pervious concrete exhibits are shared by conventional concrete pavements as well. These include minimizing heat islands and increased reflectivity. Both of these benefits are attributed to the colour of concrete, light grey, in comparison to asphalt pavement which is black in colour. The urban heat island effect occurs in urban areas with many dark surfaces that lead to the localized air temperature being higher than it would be on a comparable day in a rural environment. Research indicates that the air temperature in urban areas can be up to 4°C degrees higher than it would be in a rural setting (Pon, 2000). The effect of this increased temperature, is a higher frequency of heat related illness, especially in the

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susceptible population: children; and seniors (EPA (. P., 2009). While the effects of urban heat islands on humans are of great concern to communities and cities, reductions of urban heat islands also benefit the environment and economy. By maintaining the natural air temperature and not increasing it unnecessarily, due to dark areas, the demand for resources is not accelerated. Therefore additional resources and funds are not spent cooling buildings because of increased outdoor temperature (Pon, 2000).

1.4 ECONOMY

Pervious concrete pavements have the potential to exhibit the same low life cycle costs as conventional concrete pavements. The life cycle cost of conventional concrete pavement is low because concrete has a longer life time than other paving materials and can require less maintenance throughout the life cycle. Pervious concrete that is well designed and constructed should also exhibit similar life cycle performance (NRMCA, Economic Benefits, 2010). Pervious concrete pavement can offer economical benefits to individuals using it on their own property as it maintains the natural water cycle. Since pervious concrete is a low impact development it ensures that surrounding vegetation, such as gardens and lawns, receive natural moisture. This limits expenses for the home owner related to watering. In the case of both private and commercial properties pervious concrete can be used in a water harvesting system which reduces the water demand. In order to accommodate stormwater management systems, additional land is often required for stormwater retention ponds. Stormwater management systems also require infrastructure such as pipe networks which adds to the expense of a project. The use of pervious concrete pavement can eliminate the need for land and infrastructure to support stormwater management systems (NRMCA, 2010). Dark areas in urban centres result in urban heat islands which are harmful to the health of the community but also result in an increased expense related to cooling surrounding buildings (Pon, 2000). If urban heat islands can be mitigated the cooling costs of the surrounding community will not be increased and therefore less resources and funding will be required. The light colour of concrete reduces the amount of lighting infrastructure required to create the desired brightness of parking lots and paths during evening and night use. It is suspected that the light colour of pervious concrete pavement will have a similar benefit. In addition to less funding being spent on lighting infrastructure, less funding is required during the life cycle of the infrastructure as there are fewer assets to supply power for. Achievement of economic benefits with the use of pervious concrete contributes to the sustainability of the material.

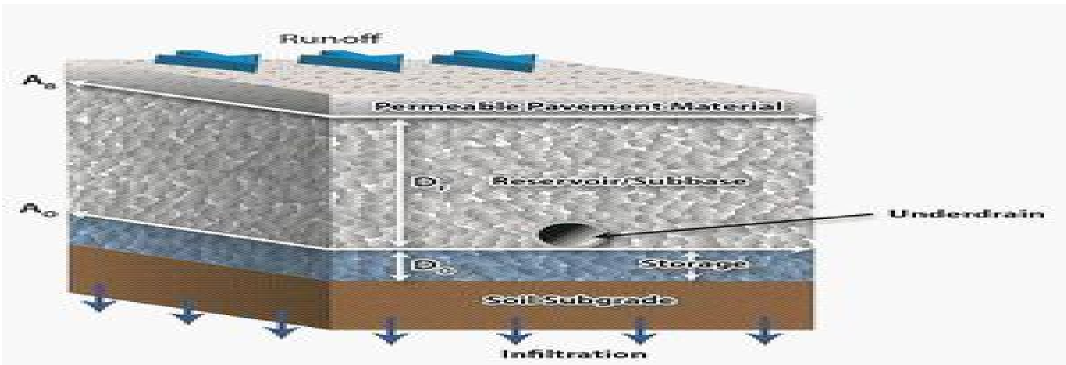

Fig. 2 Drainage system of permeable pavement

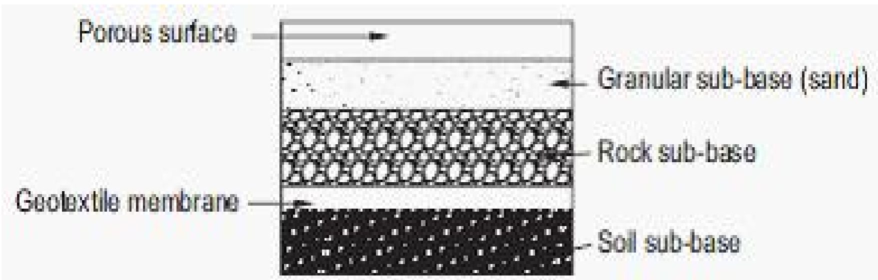

Fig. 3Typical schematic layout of a porous pavement system

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2.METHODOLOGY

2.1 Materials

To simulate mixtures for use in State Highway Administration (SHA) projects, materials often used for SHA projects were specified. Vulcan materials supplied the coarse and fine aggregates. The aggregates originated from their quarry and were distributed.A maximum of 1/2 in. diameter aggregate was used in each mix design. Fine aggregates were used to help achieve higher design strengths. Portland Type I cement was used in each mix. One control mix and three mix designs with the following admixture were batched: viscosity modifier, delayed set modifier, and cellulose fibers and were developed for the different batches and different tests to be performed:

2.2 GENERAL PROPERTIES

Void content: 18-35%

Cement: 267-415 kg/m3

w/cm ratio : 0.26 0.40

Coarse aggregate: 9.5 -19mm. little to no fine aggregate (less than 10% of wt. of total aggregate) Just enough cementitious paste to coat the coarse aggregate.

2.3 Mix Design

While pervious concrete contains the same basic ingredients as the more common conventional concrete (i.e. aggregate, Portland cement, water, and a variety of admixtures), the proportioning of ingredients is quite different. One major difference is the requirement of increased void space within the pervious concrete. The amount of void space is directly correlated to the permeability of the pavement. With low water to cement ratio, the need for void space within the mix design, and little to no fine aggregates, the conventional design of concrete needs to be adjusted accordingly. Ranges of materials commonly associated with pervious concrete are listed below. These ranges are based on previous research. Design Void Content: 15% to 25% Water to Cement Ratio: 0.27 to 0.33 Binders to Aggregate Ratio: below 0.25 the goal for the final mix design was to provide a strong, durable pervious concrete design which allowed for adequate drainage of rainwater. Reviewing the literature and past research, a 15% design void content would have allowed for higher strength and durability in the pervious concrete samples but not allowed adequate drainage based on Maryland peak storm events. A 25% void content would have allowed more than enough void space in the samples to accommodate a peak storm even in Maryland but may not have provided the strength and durability that was required for the research project. Taking into account the goals of the project and the literature review, a target void content of 20% was desired with a water-to-cement ration of 0.3. Prior to the application of the admixtures, several test mixes were performed to determine an appropriate mix design for the project. While trying to increase strength and maintaining permeability, different values of water to cement ratio were tested. Three different water-to-cement ratios were tested: 0.27, 0.30, and 0.33. Three cylinders, 4 inch diameter by 8 inch tall were cast for each ratio. During mixing, it was noted that the lowest water-to-cement ration of 0.27 was very dry. The cylinders were demolded after 24 hours and allowed to cure in a water tank. After three days, it was visually observed that the lowest water-tocement ratio had several loose aggregates not bonded together. Comparing to the literature review, past research, and the sample mix designs performed.

The standard mix proportions for the mix were as follows: Cement: Coarse Aggregate: Fine Aggregate: Water which will be equivalent to 1:4.1:0.30:0.30 by weight. The pervious concrete mix design that was used for this research project was determined from a thorough literature review of past research. The total amount of concrete to conduct the four tests (Compression Test, Tensile Test, Permeability Test, Density and Void Test) required is 0.28 cubic yard.

For consistency by taking a handful of pervious concrete mix and creating a ball. If the aggregate separated and did not maintain the ball shape, the mixture was considered too dry. If the ball had a lot of paste running off the aggregate and sticking to the glove, then the mixture was considered too wet.

2.4EXPERIMENTAL TESTS

2.4.1 Density and Void Ratio

ASTM C1688 has become one of the few accepted tests that can adequately determine effective pervious concrete mix properties such as density and void content. This test helps to determine if the freshly mixed concrete will achieve the targeted void content as specified in the mix design. The test was conducted at the University of Maryland and was done by first obtaining a cylindrical steel container with a minimum capacity of 25 cubic feet. The inside was moistened with a damp towel and excess water was removed from the bottom. The container was then weighed and the weight recorded to the nearest gram. The freshly mixed pervious concrete was scooped into the container and once it was approximately half full, a standard proctor hammer was used to compact the specimen. The hammer was dropped 20 times evenly around the cylindrical area. The container was then filled ¼ of an inch above the top lip. The proctor hammer was used again to compact the specimen using 20 evenly distributed blows. A hand trowel was used to strike off the top surface of the container and a clean towel was used to wipe down the sides. The cylinder was then weighed and the weight recorded to the nearest gram. The weight of the pervious concrete sample was found by subtracting the total weight of the cylinder and sample from the measured weight of the container.

The density and void content was found by first determining the theoretical density of the concrete computed on an air-free basis. This is computed by dividing the total mass of all materials batched by the sum of the absolute volumes of the component ingredients in the concrete mix.

2.4.2 Density and Theoretical Density of the Pervious Concrete

The absolute volumes were determined by taking the quotient of the mass of the ingredient divided by the product of its relative density times the density of water. The specific gravities for the coarse and fine aggregates were given by the aggregate supplier. The Portland cement was assumed to have specific gravity of 3.15 as stated in ASTM C 1688. Equation 1 denotes the theoretical density of the concrete computed on an air-free basis:

$T = Ms/Vs$……………………………………………………………………….…Eq.1

To calculate the actual mix density, the mass of the concrete filled container must be subtracted from the mass of the container and then divided by the volume of the container. Equation 2 denotes the density of the pervious concrete mix:

$D = (Mc-Mm)/Vm$……………………………………….………………………...Eq.2

The void content of the sample was found by the following equation:

$U = (T-D)/T \times 100\ \%$………………………………………...…………………Eq.3

The target void content of the mix design was 20%. As shown in Table 4.2, all four mix designs are within an acceptable range. The cellulose fiber mix had the lowest void content. This was primarily due to the fibers taking up a small portion of the void content.

2.4.3 Compressive Strength Test

The compressive strength test was performed on all four mix designs. Three cubes were cast from each mix design and the average of the compressive strength was used as the final number. Four different periods were used to determine the rate at which the cylinders gained strength – Day 7, Day 14 and Day 28. The test was performed at a concrete technology Laboratory P.IG.C.E Nagpur. The specimens were removed from the curing box at the day of testing and wiped clean. The diameter of each specimen was measured at the top, middle, and bottom. The average of the three diameters was used to calculate the cross-sectional area. Any specimen having a diameter varying more than 2% of any other measured diameter was not used in the compression test. All the pervious concrete samples met this requirement. The specimens were then placed under the center ring of the compression machine. The test machine used was hydraulically powered. The upper bearing block was stationary, while the lower bearing block moved up to compress the specimen. The upper bearing block was capable of tilting if the top of the specimen was not completely horizontal. Prior to testing, the surfaces of the testing machine were wiped clean. The test cylinder was then placed on the lower bearing block and centered. The load was applied at a rate corresponding to a stress increase between 28 psi/sec and 42 psi/sec. Each specimen was loaded until the load began to decrease rapidly, and a fracture was clearly evident. The maximum load applied was then recorded. The procedure was repeated at the interval of days noted earlier.

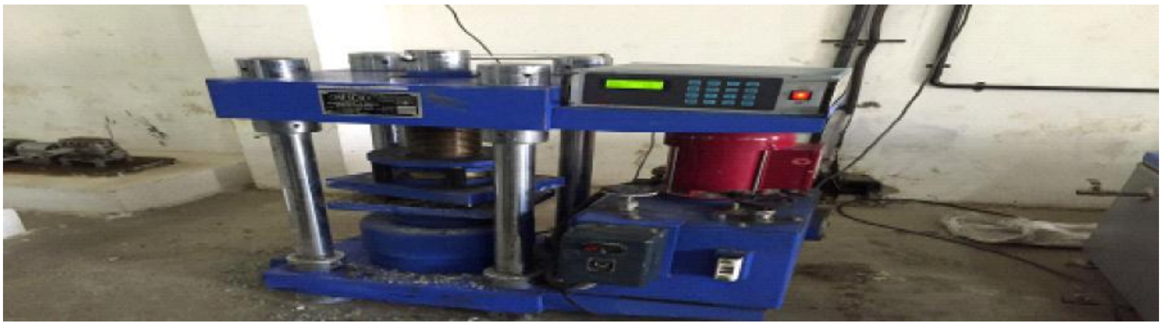

Fig.4 Compressive testing machine

The compressive strength was calculated by dividing the final maximum load recorded by the cross-sectional area of the cylindrical specimen. If the specimens had a Length-to-Diameter ratio less than 1.75, the compressive strength calculated must be modified with a correction factor. If the Length-to-Diameter ratio is greater than 1.75, no correction factor is needed. Since the ratio for all specimens exceeded 1.75, no correction factor was used. The average 28 day compressive strength varied from 2048 psi to 3227 psi. The low variation in the compressive strength can be attributed to the same method of compaction of the specimens. Each specimen was compacted at two lifts – one at the mid height and the other at the top. It has been discussed that for pervious concrete samples there is a high degree of correlation between compressive strength and the method of compaction. Due to the open voided structure of the pervious concrete, the more compaction each sample receives, the more these voids tend to close.

Fig.5 Crushing of paver

3.MATERIAL PROPERTIES

3.1 Cement

Ordinary Portland cement, 53Grade conforming to IS: 269 – 1976.Ordinary Portland cement, 53Gradewas used for casting all the Specimens. Different types of cement have different water requirements to produce pastes of standard consistence. Different types of cement also will produce concrete have a different rates of strength development. The choice of brand and type of cement is the most important to produce a good quality of concrete. The type of cement affects the rate of hydration, so that the strengths at early ages can be considerably influenced by the particular cement used. It is also important to ensure compatibility of the chemical and mineral admixtures with cement.

The cement content of a pervious concrete mix was evaluated in terms of its effect on freeze thaw durability with samples that were prepared in the laboratory. With a higher cement content, the samples showed better performance in freeze-thaw cycling. This freeze-thaw cycling was performed while the samples were continually submerged. The inclusion of more cement is predicted to lead to a thicker paste and therefore more bond development (Yang Z. , 2011). Ranges of water to cement ratios were evaluated in laboratory prepared pervious concrete mixes. A water cement ratio of 0.25 showed less freeze-thaw durability in saturated conditions than a ratio of 0.35. It is suspected that below a water cement ratio of 0.35 there may have been excessive drying and shrinkage cracking occurred (Yang Z. , 2011). Mixes prepared in the laboratory were compared for compressive strength and permeability. Samples with a higher water cement ratio, 0.33, showed the highest compressive strength results. The mix with a water cement ratio of 0.25 had the lowest compressive strength and a mix with a water cement ratio of 0.29 had compressive strength results in between. A clear relationship between density of the sample and water cement ratio and compressive strength result was present. Samples within a specific mix with higher densities had higher compressive strength results. The permeability test results did not show as clear a correlation, however a trend was present. The higher water cement ratio mixes consistently had lower permeability rates

Fig.6 Pozzolana Portland cement

3.2 Coarse Aggregate

Locally available crushed blue granite stones conforming to graded aggregate of nominal size 12.5 mm as per IS: 383 – 1970. Crushed granite aggregate with specific gravity of 2.77 and passing through 4.75 mm sieve and will be used for casting all specimens. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite. In addition to cement paste – aggregate ratio, aggregate type has a great influence on concrete dimensional stability**.**

A comparison of two pervious concrete mixes in the laboratory demonstrated that the size of aggregate can result in different void structures developing and therefore different characteristics. Pervious concrete mixes were prepared in the laboratory, one with smaller sized aggregate, 8 mm – 10 mm and the other with larger, 16 mm – 20 mm. The aggregate used in both mixes was gravel. Using x-ray scanning it was identified that the smaller aggregate mix had a higher percentage of voids and mortar than the larger aggregate mix. The hydraulic permeability was found to be lower in the smaller aggregate mix when measured, than in the larger aggregate mix, even though the smaller aggregate mix had more voids. The x-ray scans showed that although there were more voids in the smaller aggregate mix, the voids were smaller and more distributed throughout the sample than in the larger aggregate mix. The larger aggregate mix had larger voids and visibly small contact points between aggregates. Smaller aggregates have more surface area when a volume of space is considered than larger aggregates. Therefore there is more area for mortar coverage and opportunity for contact and bond development (Kringos, Vassilikou, Kotsovos, & Scarpas, 2011). Pervious concrete samples with the same void content were identified to provide different permeability rates depending on the characteristics of the voids themselves. Using binary images, x-ray microtomography and computational analysis, the characteristics of the voids in three laboratory prepared pervious concrete mixes were compared. Each mix contained a different size of aggregate. Although the void content of the three mixes was similar, the permeability increased as the aggregate size increased (2.36 mm to 12.7 mm). The images and computational analysis showed that when larger aggregate was used in the pervious concrete mix the void size increased. The permeability results suggest that larger sized voids lead to higher permeability and the void

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content does not necessarily describe this (Neithalath, Bentz, & Sumanasooriya, May 2010). The permeability of a pervious concrete pavement structure is not necessarily the determining factor as to whether the pavement performs adequately. Permeability rates have been found to increase exponentially as the void content of a pervious concrete mix increases. It is important to find a balance between void content, durability and permeability rate in a pervious concrete mix design (Schaefer, Wang, Suleiman, & Kevern, 2006; Delatte & Cleary, 2006).

Fig .7 Uniform size of aggregate

3.3 Water

Casting and curing of specimens were done with the potable water that is available in the college premises.

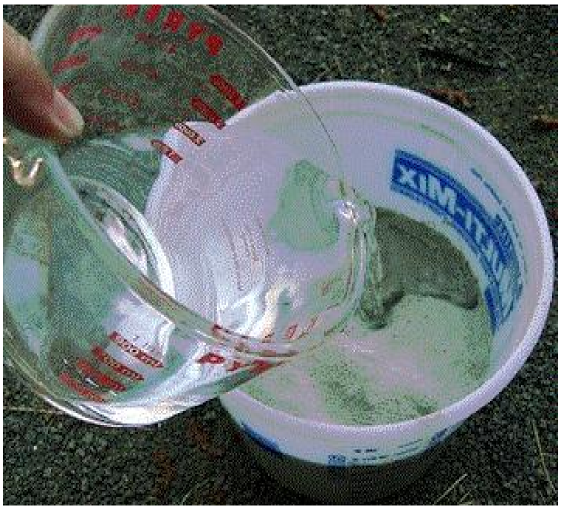


Fig.8 Water

3.4 General Properties

Void content: 18-35%

Strength: 28-281 kg/cm^2

Infiltration rate: 0.80 lt per min

Cement: 267-415 kg/m^3

W/cm ratio: 0.26- 0.40

Coarse aggregate: 9.5-19mm little to no fine aggregate (less than 10% of wt. of total aggregate) Just enough cementitious paste to coat the coarse aggregate.

3.5 Water Cement Ratio

The water cement ratio (W/C) of a concrete mix affects the characteristics of the mix and the performance. The mix designs used in this project had various W/C, ranging from 0.23 to more than 0.29. The W/C is an important descriptor of the paste in a concrete mix design. The structure of a pervious concrete mix makes the paste characteristics very important.

Fig.9 Pervious concrete mix

3.6 Experiments

Different sample blocks were made by using different proportions of cement, aggregates, admixture and water. In all of the tests no used sand at all.

Fig.7 Cube samples

Table 1. Different proportions of sample blocks (dim. 15mm*15mm*15mm)

Sample	Cement(kg.)	Coarse aggregate (kg)	Water(gm.)	Infiltration rate (lt/min.)
1	1	(20mm) 5.2	450	0.27
2	1	(20mm) 5.2	440	0.34
3	1	(16mm) 5.2	400	0.40
4	1	(16mm) 5.2	380	0.46

In the experiment,different sample blocks were made by taking different sizes of aggregates in the range of 9.5-20mm, and on trial and error method , with variable quantity of water keeping the quantity of cement and coarse aggregate same, as shown in table 1. No sand is used in all the samples as it reduces the void content and thus reduces the porosity of the block. So according to the different proportions of materials used in the above four sample blocks, the most appropriate proportion is found to be of sample 4 , having the maximum infiltration rate.

Table 2. Different proportions of paver blocks

Sample	Cement(kg.)	Coarse aggregate (kg)	Water(gm.)	Infiltration rate (lt/min.)
1	0.60	(12.5mm) 2.6	165	0.60
2	0.58	(12.5mm) 2.6	160	0.65
3	0.56	(10mm) 2.6	160	0.67
4	0.54	(10mm) 2.6	170	0.70

Over the data taken from table 1.Different proportion of sample blocks, the specifications and dimensions of the paver block mould ,(i.e. size , shape , weight of mould) the quantities of cement , coarse aggregate and water is calculated for the mould of paver block . So different samples of paver blocks were made in a lab , varying the quantities of cement and water , keeping quantity of coarse aggregate same . The size of aggregate affects the void content in the block, so coarse aggregate of sizes 12.5mm and 16mm were used in the above four samples. After calculating the infiltration rates of the four paver blocks , sample 4 has the maximum infiltration rate of 0.70 lts/min. than the rest. So it can be effectively used at the sites.

Fig.8 Permeable paver

The admixture can be used 'Apple chemie BU430 A_3&Sika Viscocrete5001' This made water release from cement particles design we filled cubes wastage was also there in filling the cubes. The top surface of cubes was closed to prevent fast evaporation of water since it is porous.The cubes were opened the next day and put in water for proper hydration of cement. These cubes were not perfectly pervious. Its base and sides (up to some height) were flat and smooth. The cement-water slurry settled down and it might have happened due to high quantity of admixture.So in all, sample no 3(final sample) was the successful one. This was made with low w/cm ratio and w/o compaction.

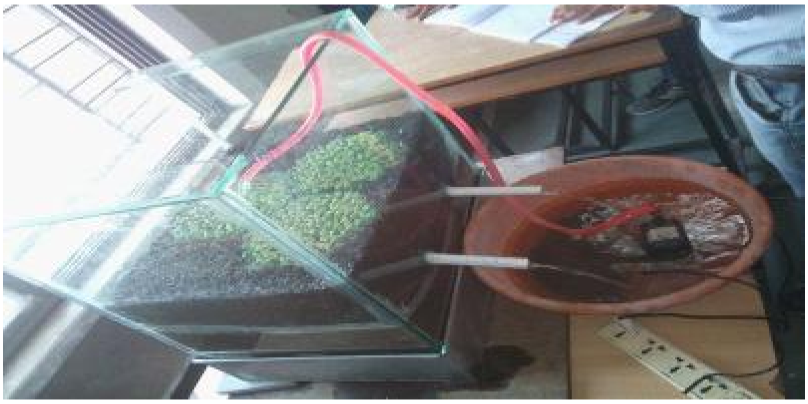
Table no.3 Specifications

Shape	**hexagonal**
Thickness-	60mm
Area	0.0331 m^2
Volume	0.00198 m^3
Weight	3.112kg
Infiltration rate	0.79 litres per min
Strength	After 14 days curing-18kg/cm^2
	After 28 days curing-24kg/cm^2
Density	1571KG/M^3
Cost for one paver	**Rs. 9.55** including cost of material, labour charges, maintenance, electricity and transportation

4. WORKING MODEL

4.1 Design

The design phase of a pervious concrete pavement project includes the mix design of the pervious concrete, the characteristics of the granular base storage layer and the entire pavement structure. The mix designs that were used in this project will be compared, the pavement structure that was developed for each field site will be discussed, and the structural performance of the pavement structures will be analyzed in this chapter.



Working model of hexagonal pavers

5. Innovations and future research

Concerning porous pavements, silica fume and super plasticizer can be added to standard porous concrete ingredients. This usually improves the compressive strength of the porous pavement to allow for higher loads depending on the application. With respect to PPS, an additional layer of heat-bonded geotextile was introduced to the Formpave sub-base.

This liner slowed down the release of small oil spillages, and their subsequent transport through the system. In case of an emergency, however, this solution cannot be used to protect large volumes of released oil, although the oil trap may significantly reduce the released amount of oil. Furthermore, the authors of this paper have recently worked with Form pave and Water Furnace Europe to develop a heating/cooling system, which can be installed within the sub-base of modern PPS.

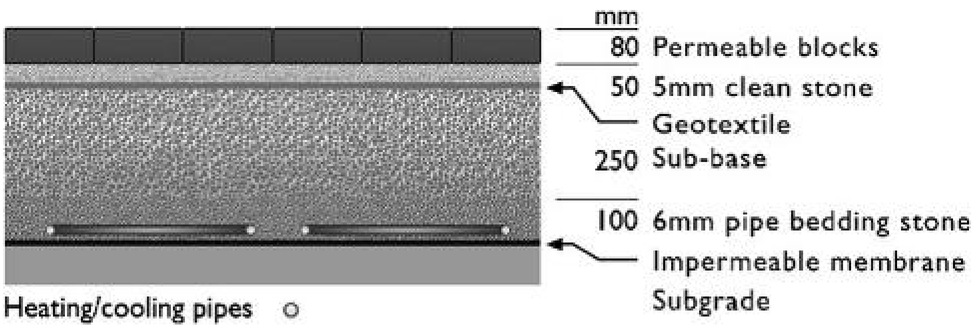


Fig.9 Tanked permeable pavement system including a heating/cooling element

The energy gained from the below-ground pump can be used for heating or cooling buildings. Natural energy can be used to heat water and subsequently reduce industrial and domestic energy bills. The system is safe, reliable and energy efficient, because heat energy is transferred from the earth to heat and cool work and domestic environments, which would otherwise rely on fossil fuels that are becoming scarce and more expensive. The research focuses also on improving the growth of microorganisms during

artificial temperature fluctuations induced by the heat pump. Further research on the short- and long-term effects of contaminants that remain in the PPS should be undertaken. The self-sustainability of these relatively new systems in comparison to traditional pavements requires further assessment. Moreover, the long-term impact of PPS on the environment is still unclear. Finally, as PPS are becoming established as environmental friendly engineering techniques, there is a need for the development of simple computer-based decision support tools for engineers and planners. Most recent attempts to incorporate PPS into a SUDS decision support model were made by the lead author.

6. Conclusion

The Pervious concrete blocks made by using uniform size of aggregate (10mm,12.5mm,16mm,20mm),and w/c ratio 0.31, allows water to pass through it with the average infiltration rate of 0.79 liter per min . So finally by trial and error method it was observed that the use of aggregates in the range of 9.5-19 mm is most suitable for making pervious pavement blocks because its infiltration rate is much higher as compared to traditional pavement blocks. Also the density of Pavement block is found to be 1571 kg/cu.cm and it is in a standard range (1500 to 2000 kg/cu.cm) but greater the density higher is the strength and lower the infiltration rate .After testing all the four samples in compressive testing machine its average strength is observed as 24 kg/cm^2 after 28 days of curing,which was not suitable for heavy loaded area but can be used in light volume areas.Pervious concrete not only serves storm water management but also removes air pollutants,water impurities thus it provides pure water to ground water sources and it also removes turbidity upto 2 to 4 NTU from surface water. Designed Pervious Pavement blocks allows transfer of water and air to root system allowing trees to flourish. It is also economical to use pervious pavement blocks as the estimating cost of one pervious pavement block is Rs.9.55 per paver which is much more less than traditional pavement blocks .

REFERENCES

1] Schlu¨ ter W, Jefferies C. Modeling the outflow from a porouspavement. Urban Water 2004;4(3):245–53.
[2] Scholz M. Practical sustainable urban drainage system decisionsupport tools. Proceedings of the Institution of Civil Engineers–En-gineering Sustainability 2006;159(3):117–25.
[3] Balkema AJ, Preisig HA, Otterpohl R, Lambert FJD. Indicators forthe sustainability assessment of wastewater treatment systems. UrbanWater 2002;4(2):153–61.
[4] Astebøl SO, Hvitved-Jacobsen T, Simonsena A. Sustainable stormwater management at Fornebu—from an airport to an industrial and residential area of the City of Oslo, Norway. Science of the TotalEnvironment 2004;334–335(Special Issue):239–49.
[5] Wilson S, Newman AP, Puehmeier T, Shuttleworth A. Performanceof an oil interceptor incorporated into a pervious pavement. Proceedings of the Institution of Civil Engineers–EngineeringSustainability 2003;156(1):51–8.
[6] Dierkes C, Go¨ bel P, Benze W, Wells J, Next generation water sensitivestorm water management techniques. In: Melbourne Water, editor.Proceedings of the second national conference on water sensitiveurban design, 2–4 September 2000, Brisbane, Australia, 2002.
[7] Andersen CT, Foster IDL, Pratt CJ. The role of urban surfaces(permeable pavements) in regulating drainage and evaporation:development of a laboratory simulation experiment. HydrologicalProcesses 1999;13(4):597–609.
[8] Pratt CJ, Newman AP, Bond PC. Mineral oil biodegradation within apermeable pavement: long-term observations. Water Science and Technology 1999;39(2):109–30.
[9] Brattebo BO, Booth DB. Long-term storm water quantity and quality performance of permeable pavement systems. Water Research 2003;37(26):4369–76.
[10] Dierkes C, Kuhlman L, Kandasamy J, Angelis G. Pollution retention capability and maintenance of permeable pavements. In: StreckerEW, editor. Proceedings of the ninth international conference onurban drainage, Portland, USA, 8–13 September 2002.
[11] Pindado MA, Aguado A, Josa A. Fatigue behavior of polymer-modified porous concretes. Cement and Concrete Research 1999;29(7):1077–83.
[12] Scholz M. Wetland systems to control urban runoff. Amsterdam:Elsevier; 2006.

[13] Choubane B, Page GC, Musselman JA. Investigation of waterpermeability of coarse graded Superpave pavements. Journal of theAssociation of Asphalt Paving Technology 1998;67(2):254–76.
[14] Mallick RB, Cooley LA, Teto MR, Bradbury RL, Peabody D. An evaluation of factors affecting permeability of Superpave designed pavements. AL, USA: NCAT Report 03-02. National Centre for Asphalt Technology, Auburn University; 2003.
[15] Booth DB, Leavitt J. Field evaluation of permeable pavement systems for improved storm water management. American Planning Association Journal 1999;65(3):314–25.
[16] James W, von Langsdorf H. Computer aided design of permeable concrete block pavement for reducing stresses and contaminants in anurban environment. In: Proceedings of the seventh international conference on concrete block paving (PAVE AFRICA), Sun City,South Africa, 12–15 October 2003.
[17] Nishigaki M. Producing permeable blocks and pavement bricks from molten slag. Waste Management 2000;20(2-3):185–92.
[18] Omoto S, Yoshida T, Hata S. Full-scale durability evaluation testing of interlocking block pavement with geotextile. In: Proceedings of the seventh international conference on concrete block paving (PAVEAFRICA), Sun City, South Africa, 12–15 October 2003.
[19] Newman AP, Puehmeier T, Kwok V, Lam M, Coupe SJ, ShutleworthA, Pratt CJ. Protecting groundwater with oil retaining perviouspavements: historical perspectives, limitations and recent develop-ments. Quarterly Journal of Engineering Geology and Hydrogeology2004;37(4):283–91.
[20] Abbot CL, Comino-Mateos L. In-situ hydraulic performance of apermeable pavement sustainable urban drainage system. Journal ofthe Chartered Institution of Water and Environmental Management2003;17(3):187–90.
[21] Pagotto C, Legret M, Le Cloirec P. Comparison of the hydraulicbehaviour and the quality of highway runoff water according to thetype of pavement. Water Research 2000;34(18):4446–54.
[22] Bean EZ, Hunt WF, Bidelspach DA, Study on the surface infiltration rate of permeable pavements. In: Sehlke G., Hayes DF, Stevens DK,editors. Proceedings of the American Society of Civil Engineers andEWRI 2004 world water and environmental resources congress, SaltLake City, UT, USA, 27 June–1 July 2004.
[23] Caoi SL, Poduska D, Zollinger DG. Drainage design and perfor-mance guidelines for uni eco-stone permeable pavement. Report forThe Uni-Group USA (21/01/1998). College Station, TX, USA:Department of Civil Engineering, The Texas A&M UniversitySystem; 1998.
[24] D'Arcy BJ, Usman F, Griffiths D, Chatfield P. Initiatives to tackle diffuse pollution in the UK. Water Science and Technology 1998;38(10):131–8.
[25] NCDENR. Updated draft manual of storm water best management practices. Public consultation document DOC–7-1. Division of Water Quality, NC, USA: North Carolina Department of Environment and Natural Resources (NCDENR); 2005.
[26] Rossia L, Krejcia V, Rauch W, Kreikenbauma S, Fankhausera R, Gujera W. Stochastic modeling of total suspended solids (TSS) in urban areas during rain events. Water Research 2005;39(26):4188–96.
[27] Coupe SJ, Smith HG, Newman AP, Puehmeier T. Biodegradation and microbial diversity within permeable pavements. European Journal of Protistology 2003;39(4):495–8.
[28] Lei L, Khodadoustb AP, Suidana MT, Tabakc HH. Biodegradation of sediment-bound PAHs in field contaminated sediment. Water Research 2005;39(2–3):349–61.
[29] Legret M, Colandini V, LeMarc C. Effects of a porous pavement with reservoir structure on the quality of runoff water and soil. Science of the Total Environment 1996;190(Special Issue):335–40.
[30] Kellems BL, Johnson PE, Sanchez F, Crowser H, Design of emergingtechnologies for control and removal of storm water pollutants. In:Bizier P, DeBarry P, editors. Proceedings of the water world and environmental resources congress, Philadelphia, PA, USA, 23–26 June 2003.
[31] Newman AP, Coupe SJ, Puehmeier T, Morgan JA, Henderson J, Pratt CJ, Microbial ecology of oil degrading porous pavementstructures. Global solutions for urban drainage. In: Strecker EW, editor. Proceedings of the ninth international conference on urban drainage, Portland, OR, USA, 8–13 September 2002. p. 1–12.
[32] Barrell RAE, Hunter PR, Nichols G. Microbiological standards for water and their relationship to health risk. Communication and Discussion in Pubic Health 2000;3(1):8–13.
[33] Yang J, Guoliang J. Experimental study of pervious concrete pavement materials. Cement and Concrete Research 2003;33(1):381–6.
[34] Scholz M, Corrigan NL, Kazemi-Yazdi S. The Glasgow SUDS Management Project: case studies (Belvidere Hospital and Celtic FCStadium areas). Environmental Engineering Science2006;23(6).